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(NASA-CR-161153) TRANSISTOR STEP STRESS
TESTING PROGRAM FOR JANTX2N2484 Final
Report (DCA Reliability Lab., Sunnyvale,
Calif.) 33 p HC A03/MF A01 CSCI 09A

N79-18256

Unclas
G3/33 16134

TRANSISTOR STEP STRESS TESTING PROGRAM

MSFC/NASA CONTRACT NUMBER
NAS8-31944

FINAL REPORT
FOR
JANTX 2N2484

JANUARY 1979

Prepared
For

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FOREWARD

This report is a summary of the work performed on NASA Contract NAS8-31944. The investigation was conducted for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Huntsville, Alabama. The Contracting Officer's Technical Representative was Mr. F. Villella.

The short-term objective of this preliminary study of transistors, diodes, and FETs was to evaluate the reliability of these discrete devices, from different manufacturers, when subjected to power and temperature step stress tests.

The long-term objective will be to gain more knowledge of accelerated stress testing for use in future testing of varieties of discrete devices, as well as to determine which type of stress should be applied to a particular type of device or design.

This report is divided as follows: description of tests, figures, tables, and appendix.



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1.0 INTRODUCTION/SCOPE

DCA Reliability Laboratory, under contract NAS8-31944 for NASA/Marshall Space Flight Center, has compiled data for the purpose of evaluating the effect of power/temperature step stress when applied to a variety of semiconductor devices. This report covers the transistor JANTX2N2484, manufactured by Raytheon and Teledyne.

1.1 Sample Distribution

Forty-eight samples from each manufacturer were divided equally (16 per group) into three groups and submitted to the processes outlined in Table I. In addition, two control sample units were maintained for verification of the electrical parametric testing.

2.0 TEST REQUIREMENTS

2.1 Electrical

All samples were tested to the parameters and test conditions shown in Table II after the prior power/temperature step stress point. These tests were performed using the Fairchild Model 600 high-speed computer-controlled test system. In addition to the computer testing, various bench testing was required on the devices.

2.2 Stress Circuit

The test circuit in Figure 1 was used to power all of the test devices during the power/temperature stress conditions. The V_{CE} was varied to obtain the maximum rated power (MRP) on at least one of the test devices. All the remaining devices were subjected to no less than 90 percent of MRP. See Figure 1 for load resistors.



2.3 Group I - Power Stress

Thirty-two units, 16 from each manufacturer, were power-stressed in 500-hour steps of 50, 100, 125, and 175 percent of maximum rated power for a total of 2500 hours or until 50 percent or more of the devices in a sample lot failed.* Electrical measurements were performed on all specified electrical parameters after each power step. See Table I.

2.4 Group II - Temperature Stress I

Thirty-two units, 16 from each manufacturer, were submitted to Temperature Stress I. Group II was subjected to a total of 1600 hours of stress at maximum rated power in increments of 160 hours with temperature steps of +25°C commencing at +75°C and terminating at +300°C or until 50 percent or more of the devices failed.* Electrical measurements were performed on all specified electrical parameters after each temperature step. See Table I.

2.5 Group III - Temperature Stress II

Thirty-two units, 16 from each manufacturer, were submitted to the Temperature Stress II. Group III was subjected to a total of 112 hours of stress at MRP, in increments of 16 hours with temperature steps of +25°C commencing at +150°C and terminating at +300°C or until 50 percent or more of the devices in a sample lot failed.* Electrical measurements were performed on all specified electrical parameters after each temperature step. See Table I.

*Conditions for failure:

- A) Opens or shorts
- B) Leakage exceeded by 100 times limit
- C) Other parameters exceed MIL limits by 50 percent or greater



3.0 DISCUSSION OF TEST RESULTS

3.1 Group I - Power Stress

3.1.1 Raytheon

Raytheon's sample lot completed the entire 2500 hour power stress without a catastrophic or parametric failure. The electrical characteristics of this sample lot remained constant throughout the entire test period. Typical characteristics of this lot's performance were:

- 1) The mean value for I_{CBO} changed 43.75pA from an initial mean of less than 1pA to a final mean of 43.75pA.
- 2) The mean value for h_{FE} changed 74.5 from an initial mean of 197.5 to a final mean of 272.0.
- 3) The mean value for $V_{CE(SAT)}$ changed 3.44mV from an initial mean of 71.94mV to a final mean of 68.5mV.

The control units for this sample lot remained constant throughout the testing for Group I.

3.1.2 Teledyne

Teledyne's sample lot completed the entire 2500 hour power stress test with one failure. The failure occurred after 150 hours during the 150 percent MRP step. Serial number 2164 failed $V_{CE(SAT)}$ by greater than 50 percent of the maximum limit. Typical characteristics of this lot's performance were:

- 1) The mean value for I_{CBO} changed 1.333pA from an initial mean of less than 1pA to a final mean of 1.333pA.
- 2) The mean value for h_{FE} changed 64.1 with an initial mean of 53.0mV to a final mean of 56.27mV.



The control units for this sample lot remained constant throughout the testing for Group I.

3.1.3 Statistical Summary - Group I

Table IV outlines the results of Group I - power stress for each of the three parameters and measurement points for both manufacturers.

3.2 Group II - Temperature Stress I

3.2.1 Raytheon

One failure from this lot occurred 160 hours into the Temperature Stress I testing at +75°C. Serial number 2120 was removed from the lot because of an open emitter-base connection (see Appendix). At 160 hours of temperature Stress I testing at +250°C (1280 hours total), nine I_{CBO} excessive leakage failures caused Raytheon's sample lot to be stopped. Serial numbers 2122, 2124, 2125, 2126, 2131, 2132, 2133, and 2134 failed by more than 100 times the maximum leakage limit specified for these devices. Typical characteristics of Raytheon's sample lot performance were:

- 1) The mean value for I_{CBO} changed 555.5nA from an initial mean of 114.4pA to a final mean of 555.5nA.
- 2) The mean value for h_{FE} changed 14.1 from an initial mean of 207.2 to a final mean of 221.3.
- 3) The mean value for $V_{CE(SAT)}$ changed 9.77mV from an initial mean of 70.5mV to a final mean of 80.27mV.

The control units for this lot remained constant throughout the Temperature Stress I testing.

3.2.2 Teledyne

At 160 hours into testing of Teledyne's lot at +200°C (960 hours total), two catastrophic failures were removed. Serial numbers 3181 and 3184 failed because of excessive I_{CBO} leakages. At 160 additional hours (1120 hours total) at +225°C, this lot experienced three catastrophic and two parametric failures. Serial number 2177 was verified by failure analysis as having a loose internal base bond wire due to temperature stress (see Figure A-2). Serial numbers 2182 and 2191 were removed from the lot because of excessive I_{CBO} leakages. Serial numbers 2187 and 2189 were limit failures at h_{FE} . At 160 additional hours (1280 hours total), at +250°C into testing, Teledyne's lot was stopped because of three additional catastrophic rejects, causing more than 50 percent of this sample lot to be failures. Serial numbers 2178, 2179, and 2188 were removed because of excessive I_{CBO} leakages. Typical characteristics of this lot's performance were:

- 1) The mean value for I_{CBO} changed 97.6pA from an initial mean of 97.5pA to a final mean of less than 1pA.
- 2) The mean value for h_{FE} changed 51.5 from an initial mean of 156.1 to a final mean of 104.6.
- 3) The mean value for $V_{CE(SAT)}$ changed 22.1mV from an initial mean of 51.63mV to a final mean of 73.73mV.

The control units for this sample lot remained constant throughout the entire Group II testing.

3.2.3 Statistical Summary

Table V of this report outlines the results of Group II Temperature Stress I testing for each of the three electrical parameters and all of the measurement points pertaining to both Raytheon and Teledyne.



3.3 Group III - Temperature Stress II

3.3.1 Raytheon

After 16 hours at +150°C of testing, this lot had one catastrophic failure. Serial number 2200 was removed from this lot because $V_{CE(SAT)}$ was reading greater than 150 percent of the maximum limit. After 16 hours at 275°C (96 hours total) into testing, the lot had three additional failures. Two of the failures, serial numbers 2197 and 2207, were failing $V_{CE(SAT)}$ by greater than 150 percent of the maximum limit. Serial number 2145, the third failure at this point failed h_{FE} by less than 150 percent of the minimum limit. Typical characteristics of this lot's performance were:

- 1) The mean value for I_{CBO} changed 17.29pA from an initial mean of 85.62pA to a final mean of 68.33pA.
- 2) The mean value for h_{FE} changed 81.32 from an initial mean of 163.4 to a final mean of 82.08.
- 3) The mean value for $V_{CE(SAT)}$ changed 2.86mV from an initial mean of 52.31mV to a final mean of 55.17mV.

The control units for this sample lot remained constant throughout the entire Group III testing.

3.3.2 Teledyne

Teledyne's sample lot went 96 hours into Group III testing without a failure. It was not until 16 hours at +300°C (112 hours total), when this sample lot had one catastrophic failure. Serial number 2145 was pulled as a failure when I_{CBO} read greater than 150 percent of the maximum limit. Typical characteristics of this sample lot's performance were:

- 1) The mean value for I_{CBO} changed 18.9nA from an initial mean of 81.25pA to a final mean of 18.9nA.



- 2) The mean value for h_{FE} changed 14.6 from an initial mean of 211.9 to a final mean of 197.3.
- 3) The mean value for $V_{CE(SAT)}$ changed 5.69mV from an initial mean of 66.0mV to a final mean of 60.31mV.

The control units for this sample lot remained constant throughout the entire Group III testing.

3.3.3 Statistical Summary

Table VI outlines the results for Group III - Temperature Stress II testing on each of the three electrical parameters specified for this job lot. Results are recorded at each measurement point for both manufacturers.

4.0 FINAL DATA SUMMARY

Table VII statistically summarizes the change in the mean value from the zero-hour data to the final data. The graphs of Figures 2 and 4 plot the cumulative percent failures versus the temperature stress level for Group II - Temperature Stress I, and Group III - Temperature Stress II. The graphs of Figures 3 and 5 plot the time step for Group II (160 hours) and Group III (16 hours) versus the temperatures T_1 and T_2 calculated from Figures 2 and 4. Tables VIII and IX summarize the failures encountered for all three stress groups. The failures are separated into two categories: catastrophic failures in Table VIII and parametric failures in Table IX. The data from Table VIII was used as a source for the graphs in Figures 2 and 4. Figures 2 and 4 were used as a source for the graphs in 3 and 5 respectively. Junction temperature is plotted on an inverse hyperbolic scale.

5.0 CONCLUSIONS

Both manufacturers' parts held up well throughout the Group I - Power Stress process. Raytheon had no failures and Teladyne suffered only one failure during the entire Group I testing.



Following somewhat of a pattern in the Group II - Temperature Stress I process, both manufacturers' sample lots had to be stopped at the $+250^{\circ}\text{C}$ step at 1280 hours⁽¹⁾ into testing. Figures 1 and 2 and Table VIII reveal that the Raytheon sample lot shows 9 out of 10 failures at the $+250^{\circ}\text{C}$ ⁽¹⁾ step of the process. Teledyne's sample lot shows a more even distribution of failures starting from the $+200^{\circ}\text{C}$ ⁽²⁾ step, through the $+250^{\circ}\text{C}$ ⁽³⁾ step where, like Raytheon's sample lot, the job was stopped because the reject rate exceeded 50 percent of the sample lot.

Appendix A provides samples taken from both lots. Note that both lots develop aluminum gold intermetallic formations, "purple plague," at the $+250^{\circ}\text{C}$ step. This "purple plague" could possibly be caused by the high temperature stress. The Raytheon samples all suffer from excess leakage which can reasonably be ascribed to the movement of impurities resulting from excess die temperature. On the Teledyne samples, the gold flowed away from the wires into the aluminum to an unusual extent. Note that this extreme attack on the gold may be due to an unusually high proportion of silicon doping in the aluminum metallization.

Raytheon's sample lot yielded the most failures in the Group III - Temperature Stress II process. One failure came early in the testing at the $+150^{\circ}\text{C}$ ⁽⁴⁾ step due to a $V_{\text{CE(SAT)}}$ limit failure. Three more failures occurred at the $+275^{\circ}\text{C}$ ⁽⁵⁾ step of the process due to two I_{CBO} leakage failures and one h_{FE} limit failure. Teledyne's lot proved to be the stronger lot during this testing, with one failure which came at the last temp step ($+300^{\circ}\text{C}$)⁽⁶⁾ and was due to an excessive I_{CBO} leakage. A plot showing cumulative failure distribution for this testing was drawn

Notes 1 through 6 defined in the Conclusion Notes, page 9.



for the Teledyne lot (Figures 4 and 5), but a plot for Raytheon's sample lot could not be drawn due to an insufficient number of failure points (Figures 2 and 3). Figures 4 and 5 display the data for Teledyne's sample lot which is used to calculate an activation energy of .90eV.

A broken circle around a marked point denotes a freak failure not calculated as part of the regression line. A solid circle around a marked point denotes an isolated failure point. The regression line was drawn using the least square method.

The activation energy was calculated from the formula:

$$E = \left[\ln \left(\frac{t_1}{t_2} \right) \right] \left[\frac{8.63 \times 10^{-5} \text{ eV/}^\circ\text{K}}{\left(\frac{1}{T_1 + 273} \right) - \left(\frac{1}{T_2 + 273} \right)} \right] \text{ eV}$$

Where: t_1 = step of Group II - Temp Stress I = 160 hrs.

t_2 = step of Group III - Temp Stress II = 16 hrs.

T_1 = temperature in $^\circ\text{C}$ of 16% failure for Group II.

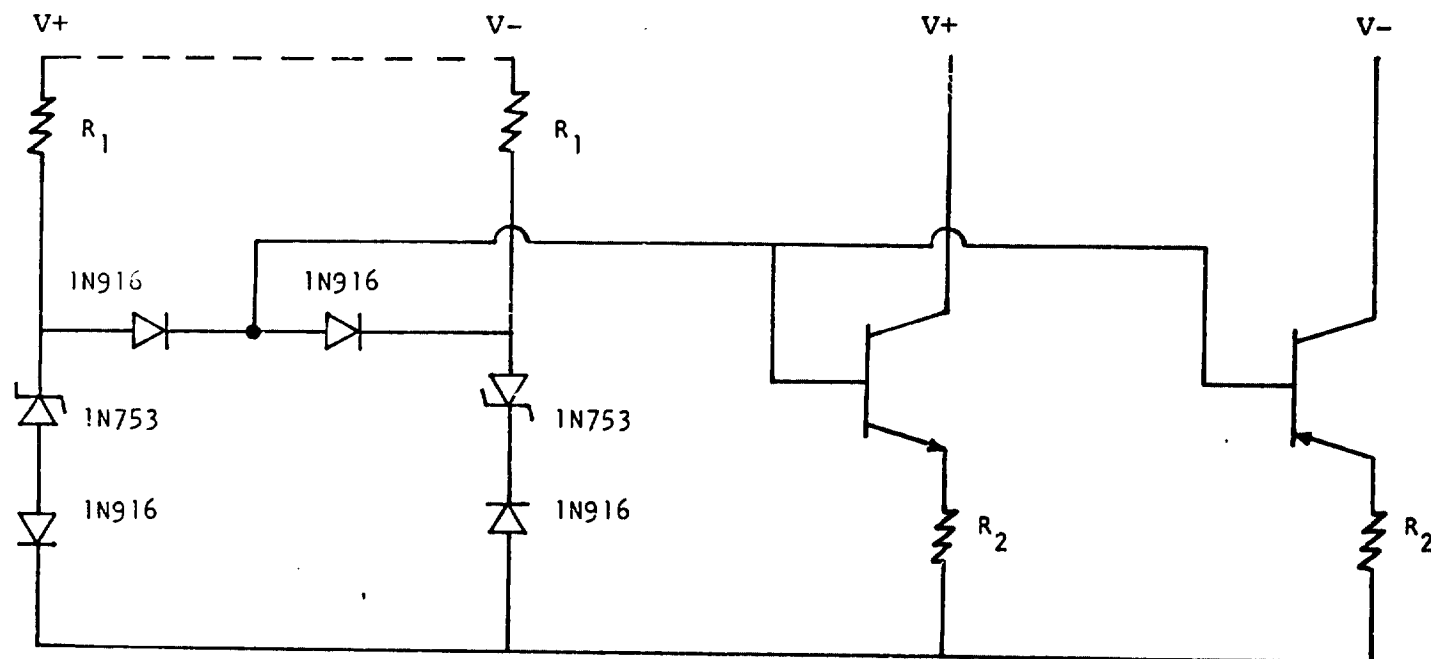
T_2 = temperature in $^\circ\text{C}$ of 16% failure for Group III.

CONCLUSION NOTES

- (1) 160 hours at +250°C (1280 hours total)
- (2) 160 hours at +200°C (960 hours total)
- (3) 160 hours at +250°C (1280 hours total)
- (4) 16 hours at +150°C (16 hours total)
- (5) 16 hours at +275°C (96 hours total)
- (6) 16 hours at +300°C (112 hours total)



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NOTES: $R_1 = 800 \pm 5\%$, 2W. $R_2 = 392 \Omega \pm 1\%$, 1/2W. See Table III for V values.

Use V+ for NPN Transistors; Use V- for PNP Transistors.

FIGURE 1
Power/Temperature Stress Circuit
JANTX2N2484



RAYTHEON

JANTX2N2484

* JUNCTION TEMPERATURE (°C)

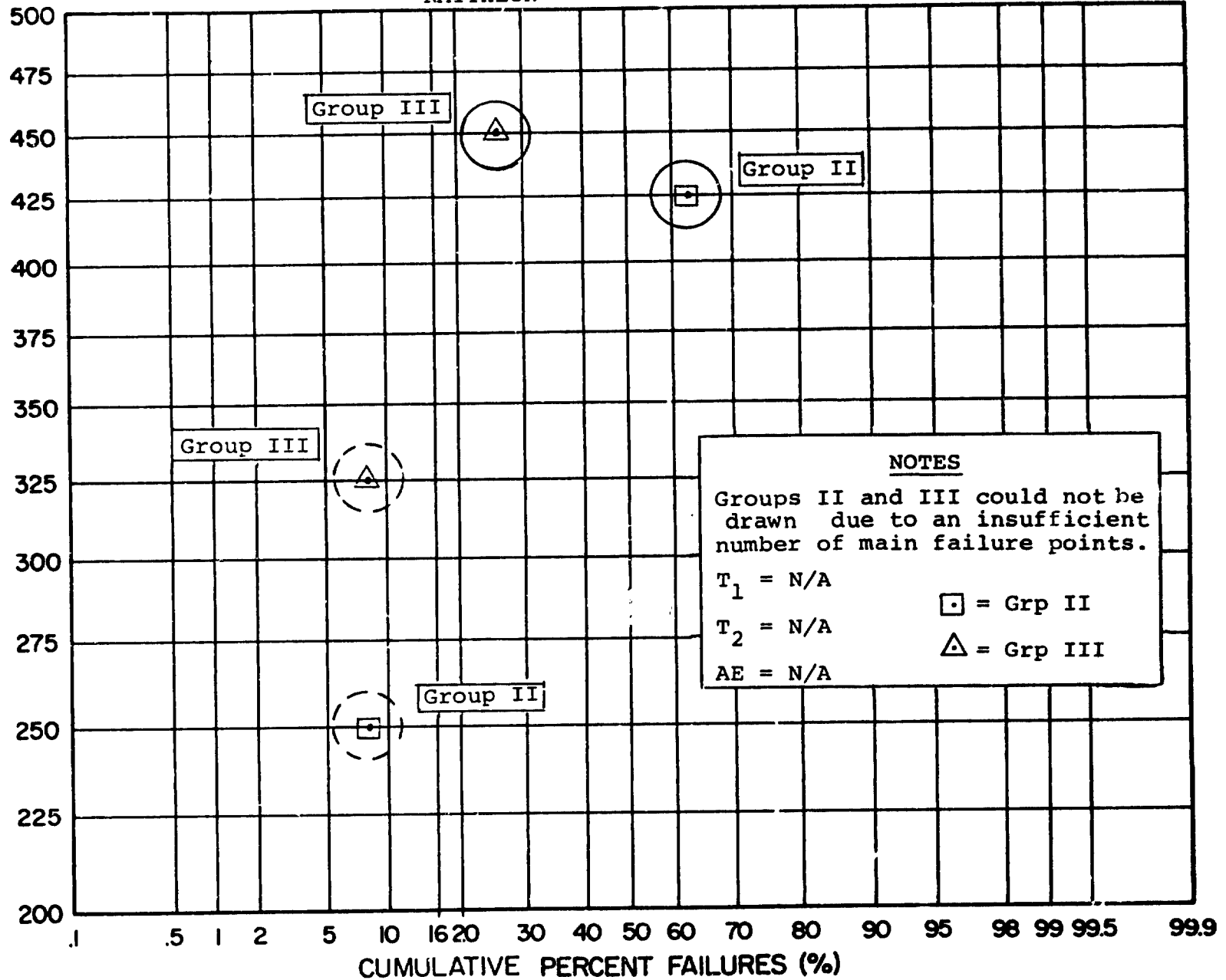


FIGURE 2

Cumulative Percent Failures Versus Junction Temperature, Raytheon

JANTX2N2484



* JUNCTION TEMPERATURE (°C)

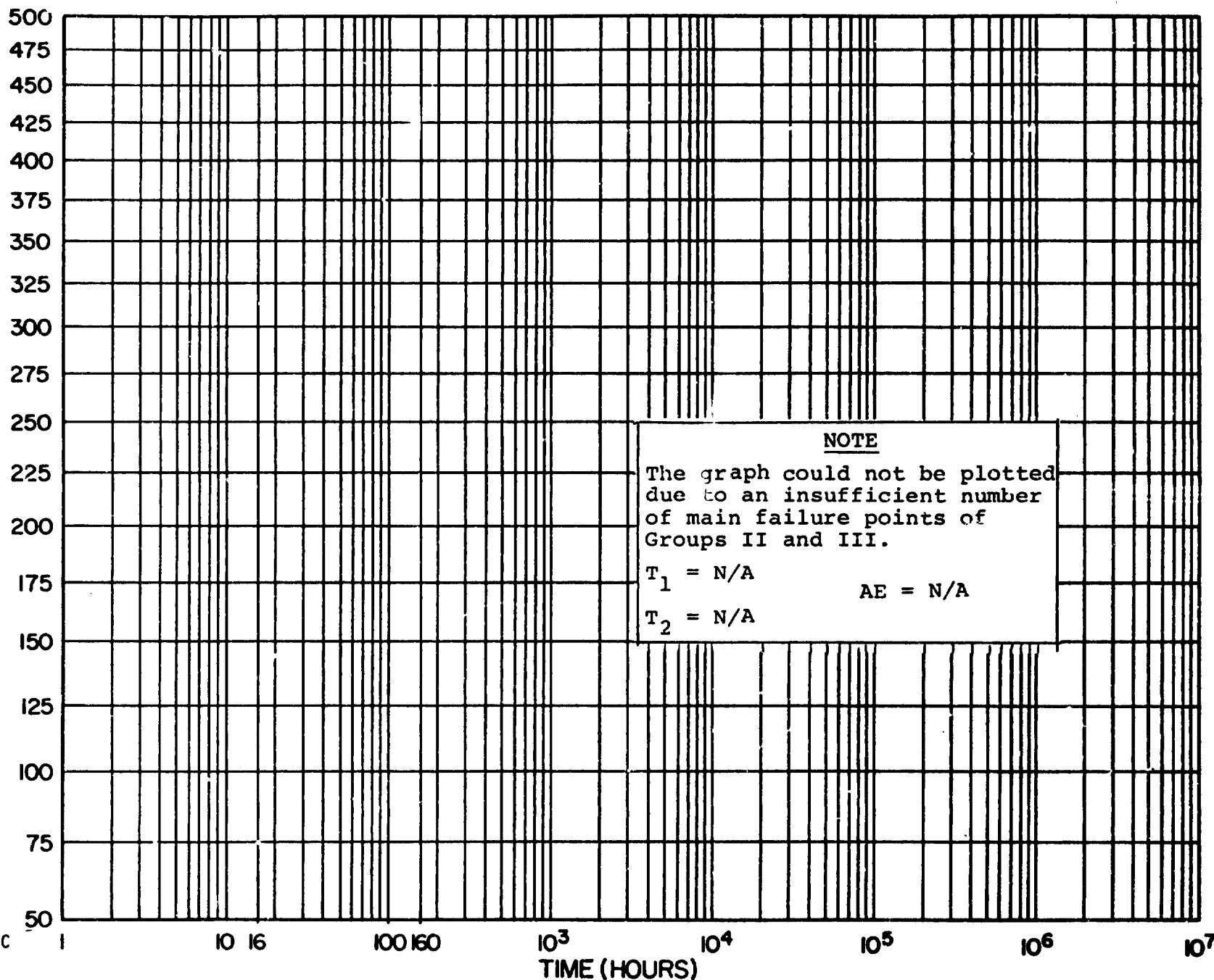


FIGURE 3
Time Steps Versus Junction Temperature, Raytheon



TELEDYNE

JANTX2N2484

* JUNCTION TEMPERATURE (°C)

 T_1 T_2 $T_1 = 381^\circ\text{C}$ $T_2 = 492^\circ\text{C}$

AE = .90eV

□ = Grp II

△ = Grp III

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*NOTE

$$T_J \approx T_A + 175^\circ\text{C}$$

CUMULATIVE PERCENT FAILURES (%)

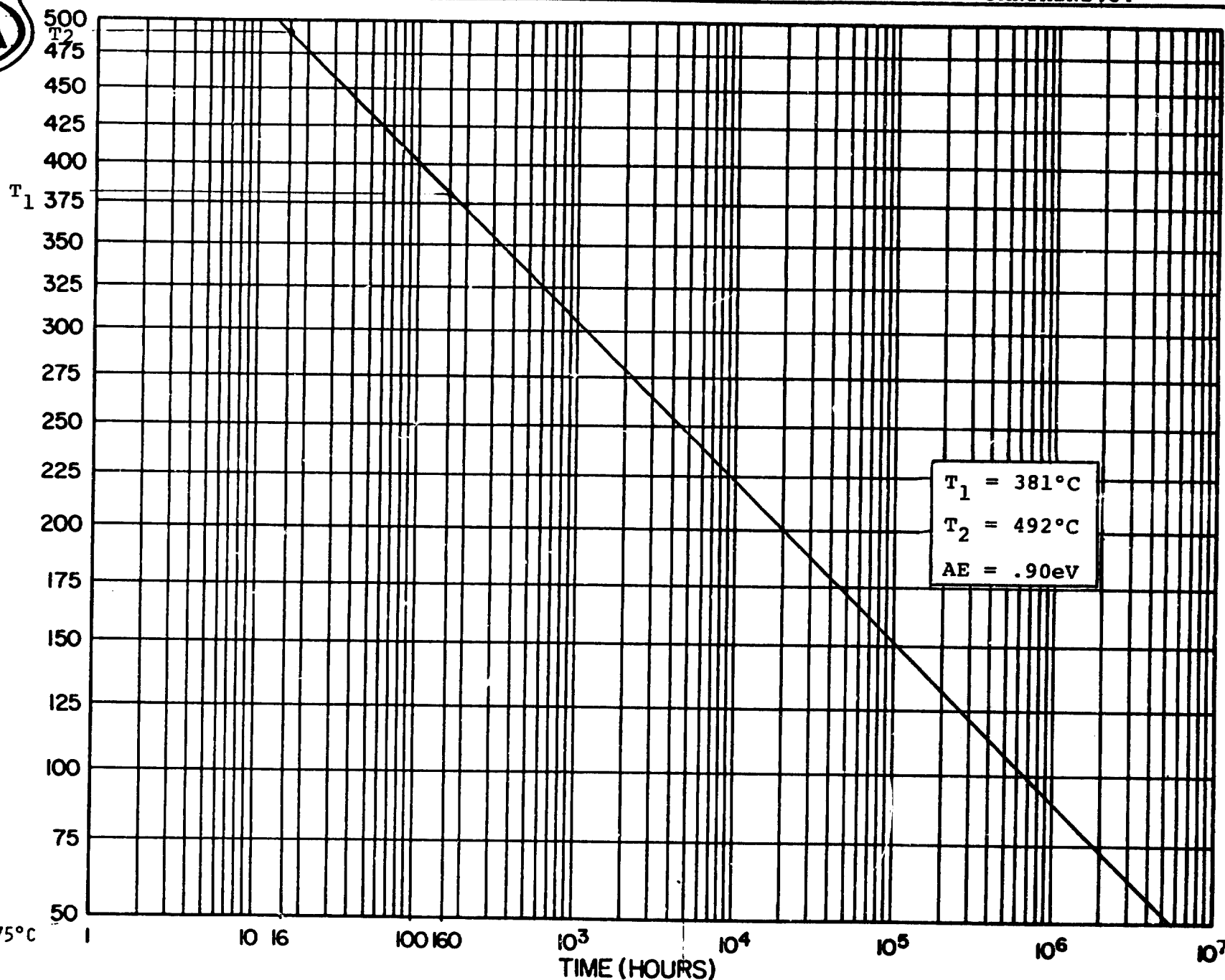
FIGURE 4

Cumulative Percent Failures Versus Junction Temperature, Teledyne

JANTX2N2484



* JUNCTION TEMPERATURE (°C)



*NOTE

$$T_J \approx T_A + 175^\circ\text{C}$$

TIME (HOURS)

FIGURE 5

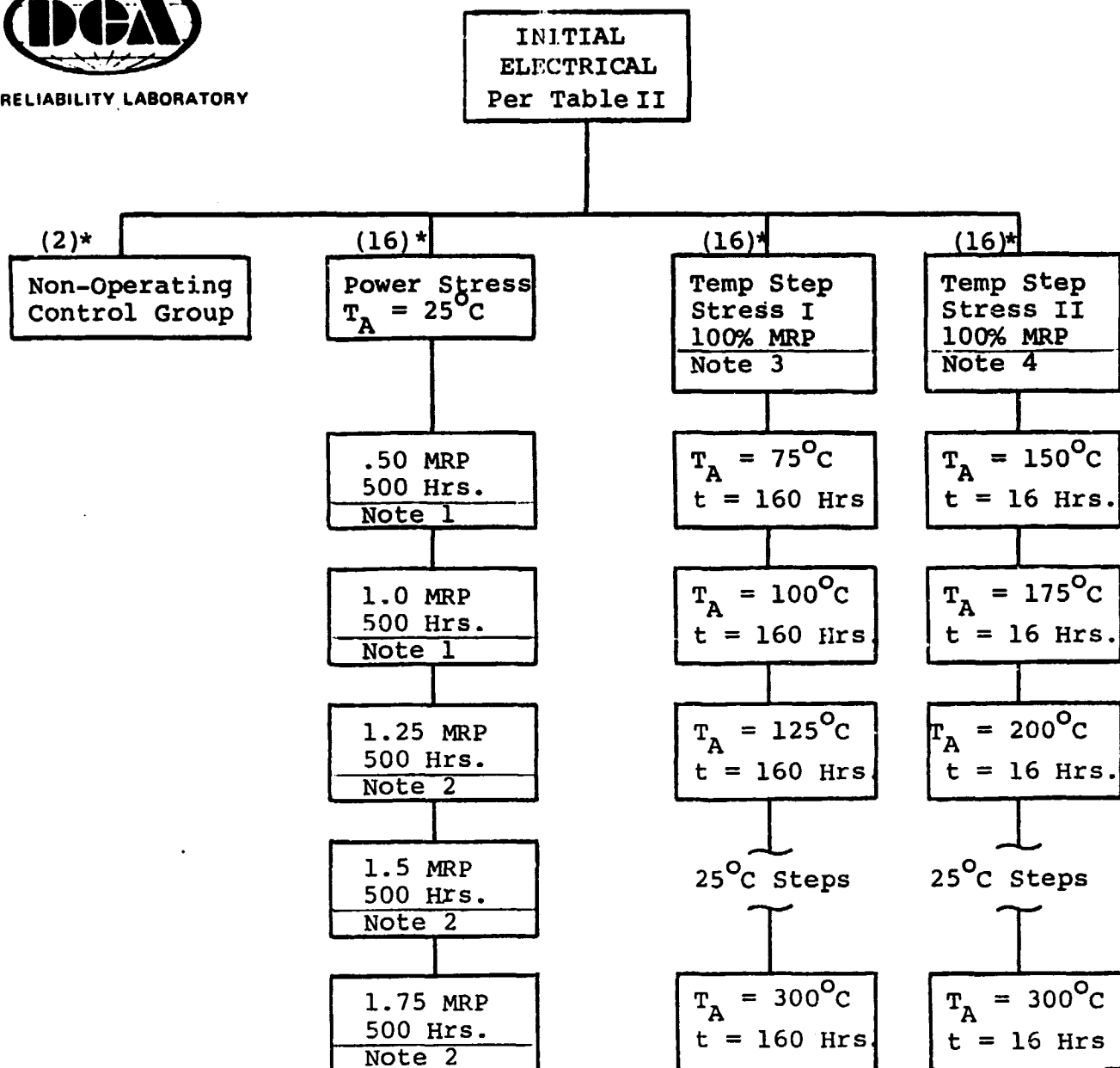
Time Steps Versus Junction Temperature, Teledyne



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TABLE I. Test Flow Diagram.

JANTX2N2484



*Quantity per manufacturer (Raytheon and Teledyne)

NOTES:

1. Electrical measurements per Table II were made at 50, 150, 250 and 500 hours.
2. Electrical measurements per Table II were made at 10, 25, 50, 150, 250 and 500 hours.
3. Electrical measurements per Table II were made at the end of each 160 hours.
4. Electrical measurements per Table II were made at the end of each 16 hours.



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TABLE II
PARAMETERS AND TEST CONDITIONS

PARAMETER	CONDITIONS	SPEC LIMITS		CAT. LIMITS ^{1/}		UNITS
		MIN	MAX	MIN	MAX	
I_{CBO}	Per MIL-STD-750 Method 3036, Bias Cond D $V_{CB} = 45V$	---	10	---	1000	nAdc
h_{FE}	$V_{CE} = 5V$ $I_C = 1\mu A$	45	---	22.5	---	---
$V_{CE(SAT)}$	$I_C = 1mA$ $I_B = 100\mu A$	--	0.3	---	0.45	Vdc

NOTES: ^{1/} In addition, any opens or shorts shall be considered catastrophic.

TABLE III
POWER STRESS BURN-IN CONDITIONS

$I_C = 14.4 \text{ mA}$	
V_{CE}	Percent P_D
12.5V	50
25.0V	100
31.25V	125
37.5V	150
43.75V	175

TABLE IV
GROUP I. POWER STRESS DATA SUMMARY

PART #JANTX2N2484

PARAMETER CONDITIONS AND LIMIT	$I_{CBO} = 10\text{nA (max)}$ $V_{CB} = 45\text{V}$		$h_{FE} = 45 \text{ (min)}$ $V_{CE} = 5\text{V}$ $I_C = 1\mu\text{A}$		$V_{CE(SAT)} = 0.3\text{V (max)}$ $I_C = 1\text{mA}$ $I_B = 100\mu\text{A}$	
	RAYTHEON	TELEDYNE	RAYTHEON	TELEDYNE	RAYTHEON	TELEDYNE
INITIAL DATA						
MIN VALUE	0.0pA	0.0pA	133.00	118.00	59.0mV	49.0mV
MAX VALUE	0.0pA	0.0pA	250.00	200.00	84.0mV	61.0mV
MEAN	0.0pA	0.0pA	197.50	159.30	71.94mV	53.0mV
STD. DEV.	0.0pA	0.0pA	32.46	18.65	8.721mV	3.775mV
Δ MEAN VALUE INITIAL TO POST STRESS						
50% POWER						
50 HOURS	0.0pA	0.0pA	4.40	0.00	0.44mV	0.63mV
150 HOURS	0.0pA	0.0pA	6.20	4.50	0.12mV	0.19mV
250 HOURS	0.0pA	0.0pA	6.20	3.10	0.44mV	0.56mV
500 HOURS	-15.0pA	<1.0pA	5.80	3.10	-0.56mV	-0.44mV
100% POWER						
550 HOURS	0.0pA	0.0pA	5.80	3.10	-0.38mV	-0.06mV
650 HOURS	0.0pA	0.0pA	6.20	3.60	-0.13mV	-0.06mV
750 HOURS	0.0pA	0.0pA	6.20	2.70	-0.06mV	0.25mV
1000 HOURS	-1.25pA	0.0pA	6.20	2.70	-0.06mV	0.44mV
125% POWER						
1010 HOURS	0.0pA	0.0pA	2.60	-1.20	0.12mV	0.81mV
1025 HOURS	0.0pA	-49.37pA	5.80	-0.20	-0.38mV	0.31mV
1050 HOURS	0.0pA	0.0pA	9.40	0.90	0.25mV	0.75mV
1150 HOURS	0.0pA	0.0pA	12.0	3.00	0.19mV	0.31mV
1250 HOURS	0.0pA	0.0pA	13.4	2.70	-0.38mV	0.63mV
1500 HOURS	0.0pA	0.0pA	13.4	2.70	-1.19mV	0.31mV

(CONTINUED)

TABLE IV. (CONTINUED)
GROUP I. POWER STRESS DATA SUMMARY

PART #JANTX2N2484

PARAMETER CONDITIONS AND LIMIT	$I_{CBO} = 10\text{nA (max)}$ $V_{CB} = 45\text{V}$		$h_{FE} = 45 \text{ (min)}$ $V_{CE} = 5\text{V}$ $I_C = 1\mu\text{A}$		$V_{CE(SAT)} = 0.3\text{V(max)}$ $I_C = 1\text{mA}$ $I_B = 100\mu\text{A}$	
	RAYTHEON	TELEDYNE	RAYTHEON	TELEDYNE	RAYTHEON	TELEDYNE
INITIAL DATA	0.0pA	0.0pA	133.00	118.00	59.0mV	49.0mV
MIN VALUE	0.0pA	0.0pA	250.00	200.00	84.0mV	61.0mV
MAX VALUE	0.0pA	0.0pA	197.50	159.30	71.94mV	53.0mV
MEAN	0.0pA	0.0pA	32.46	18.65	8.721mV	3.775mV
STD. DEV.						
Δ MEAN VALUE INITIAL TO POST STRESS						
150% POWER						
1510 HOURS	0.0pA	0.0pA	35.9	20.40	-1.19mV	0.38mV
1525 HOURS	0.0pA	0.0pA	43.4	34.80	-1.63mV	0.56mV
1550 HOURS	0.0pA	0.0pA	49.7	41.80	-0.06mV	0.69mV
1650 HOURS	-57.5pA	0.0pA	64.5	54.00	-2.13mV	1.06mV
1750 HOURS	-38.75pA	0.0pA	64.8	54.20	-2.50mV	621.4mV
2000 HOURS	-40.62pA	0.0pA	64.5	53.40	-2.88mV	0.87mV
175% POWER						
2010 HOURS	-42.50pA	0.0pA	67.3	54.20	-2.69mV	1.07mV
2025 HOURS	-35.0pA	0.0pA	72.7	64.20	-2.88mV	1.53mV
2050 HOURS	-35.62pA	0.0pA	72.9	64.20	-2.81mV	1.67mV
2150 HOURS	-38.12pA	0.0pA	74.6	66.00	-2.75mV	2.27mV
2250 HOURS	-43.12pA	0.0pA	74.8	66.30	-3.00mV	3.27mV
2500 HOURS	-43.75pA	-1.333pA	74.5	64.10	-3.44mV	3.27mV
FINAL DATA						
MIN VALUE	0.0pA	0.0pA	174.0	200.0	58.0mV	49.0mV
MAX VALUE	700.0pA	20.0pA	333.0	286.0	81.0mV	73.0mV
MEAN	43.75pA	1.333pA	272.0	223.4	68.5mV	56.27mV
STD. DEV.	169.4pA	4.989pA	53.57	22.41	8.016mV	6.688mV

TABLE V
GROUP II. TEMPERATURE STRESS DATA SUMMARY
(160 HOUR)

PARAMETER CONDITIONS AND LIMIT	$I_{CBO} = 10\text{nA (max)}$ $V_{CB} = 45\text{V}$		$h_{FE} = 45 \text{ (min)}$ $V_{CE} = 5\text{V}$ $I_C = 1\mu\text{A}$		$V_{CE(SAT)} = 0.3\text{V (max)}$ $I_C = 1\text{mA}$ $I_B = 100\mu\text{A}$	
	RAYTHEON	TELEDYNE	RAYTHEON	TELEDYNE	RAYTHEON	TELEDYNE
INITIAL DATA						
MIN VALUE	20.0pA	0.00pA	133.00	125.00	57.0mV	45.0mV
MAX VALUE	190.0pA	140.0pA	333.00	182.00	84.0mV	61.0mV
MEAN	114.4pA	97.5pA	207.20	156.10	70.5mV	51.63mV
STD. DEV.	37.41pA	36.66pA	50.46	14.17	8.66mV	4.241mV
Δ MEAN VALUE POST 160 HRS. INITIAL TO POST STRESS						
TOTAL HOURS: (T_A)						
160 + 75°C	510.0pA	97.5pA	0.10	-0.70	620.2mV	- 0.13mV
320 +100°C	- 114.4pA	97.5pA	15.50	8.80	0.90mV	0.31mV
480 +125°C	- 114.4pA	97.5pA	35.70	17.50	- 1.63mV	- 0.19mV
640 +150°C	- 114.4pA	97.5pA	56.90	32.60	- 3.57mV	- 0.38mV
800 +175°C	7.60pA	97.5pA	65.90	36.30	- 4.83mV	0.25mV
960 +200°C	* - 114.4pA	97.5pA	59.90	22.30	- 7.43mV	2.37mV
1120 +225°C	- 63.07pA	92.5pA	63.10	- 29.50	- 8.43mV	4.37mV
1280 +250°C	* 555.4nA	97.5pA	14.10	- 51.50	9.77mV	22.10mV
1440 +275°C	TEST	TEST	TEST	TEST	TEST	TEST
1600 +300°C	STOPPED	STOPPED	STOPPED	STOPPED	STOPPED	STOPPED
FINAL DATA						
LAST STRESS Temp(T_A)	+250°C	+250°C	+250°C	+250°C	+250°C	+250°C
MIN VALUE	0.00pA	0.00pA	133.00	24.70	54.0mV	47.0mV
MAX VALUE	5.36pA	0.00pA	333.00	222.00	159.0mV	253.0mV
MEAN	555.5nA	0.00pA	221.30	104.60	80.27mV	73.73mV
STD. DEV.	1.415pA	0.00pA	67.17	73.30	25.19mV	57.15mV

* CATASTROPHIC REJECT(S) REMOVED FROM DATA AT THIS POINT

TABLE VI
GROUP III. TEMPERATURE STRESS DATA SUMMARY
(16 HOUR)

PARAMETER CONDITIONS AND LIMIT	$I_{CBO} = 10\text{nA (max)}$ $V_{CB} = 45\text{V}$		$h_{FE} = 45 \text{ (min)}$ $V_{CE} = 5\text{V}$ $I_C = 1\mu\text{A}$		$V_{CE(SAT)} = 0.3\text{V(max)}$ $I_C = 1\text{mA}$ $I_B = 100\mu\text{A}$	
	RAYTHEON	TELEDYNE	RAYTHEON	TELEDYNE	RAYTHEON	TELEDYNE
INITIAL DATA						
MIN VALUE	60.0pA	30.0pA	133.00	154.00	47.0mV	49.0mV
MAX VALUE	110.0pA	100.0pA	182.00	286.00	57.0mV	86.0mV
MEAN	85.62pA	81.25pA	163.40	211.90	52.31mV	66.0mV
STD. DEV.	12.23pA	15.76pA	16.39	33.90	3.531mV	9.152mV
Δ MEAN VALUE POST 16 HRS. INITIAL TO POST STRESS						
TOTAL HOURS (T_A)						
16 +150°C	-23.1pA	13.75pA	-1.9	0.00	621.39mV	0.38mV
32 +175°C	1.05pA	13.12pA	4.8	24.0	0.42mV	0.94mV
48 +200°C	- 8.95pA	- 3.13pA	20.3	39.9	0.96mV	-3.06mV
64 +225°C	- 9.62pA	4.37pA	35.7	58.5	- 0.18mV	-4.12mV
80 +250°C	-14.29pA	- 2.5pA	38.2	54.3	7.49mV	-4.31mV
96 +275°C	- 0.95pA	184.95pA	-56.3	52.3	- 50.93mV	-7.25mV
112 +300°C	-17.29pA	18.92nA	-81.32	-14.6	2.86mV	-5.69nV
FINAL DATA						
LAST STRESS Temp. (T_A)	+300°C	+300°C	+300°C	+300°C	+300°C	+300°C
MIN VALUE	20.0pA	0.00pA	22.00	50.00	49.0mV	44.0mV
MAX VALUE	100.0pA	293.0nA	200.00	286.00	60.0mV	74.0mV
MEAN	68.33pA	19.0nA	82.08	197.30	55.17mV	60.31mV
STD. DEV.	23.03pA	70.78nA	52.72	57.66	4.317mV	8.454mV



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TABLE VII
FINAL DATA SUMMARY

PARAMETER	SPECIFICATIONS LIMIT		U N I T S	MEAN INT. DATA	AVERAGE Δ IN MEAN VALUE					
	MIN	MAX			POWER STRESS		TEMPERATURE STRESS I		TEMPERATURE STRESS II	
					RAYTHEON	TELEDYNE	RAYTHEON	TELEDYNE	RAYTHEON	TELEDYNE
I _{CBO}		10	nA		-.01505	-.00199	*69.425	-.9688	-.01045	+2.7329
h _{FE}	45		-		+33.20	+25.704	+38.90	+4.4750	-5.7886	+32.057
V _{CE (SAT)}		0.3	V		-.00114	+.02472	+.07562	+.00388	+.08314	-.00330

NOTE: Catastrophic reject(s) removed from data.

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TABLE VIII STEP STRESS CATASTROPHIC FAILURE SUMMARY

JAN TX2N2484

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
100% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
125% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
150% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	0	-
100 hr.	0	-	1	A
100 hr.	0	-	0	-
250 hr.	0	-	0	-
175% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-

GROUP II 160 HR. TEMP. STEPS

TEST STEP (T _A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75°C	1	C	0	-
175°C	0	-	0	-
125°C	0	-	0	-
160°C	0	-	0	-
175°C	0	-	0	-
200°C	0	-	2	B
225°C	0	-	3	B
250°C	9	B	3	B
275°C	JOB STOPPED			
300°C	JOB STOPPED			

GROUP III 16 HR. TEMP. STEPS

TEST STEP (T _A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150°C	1	A	0	-
175°C	0	-	0	-
200°C	0	-	0	-
225°C	0	-	0	-
250°C	0	-	0	-
275°C	2/1	A/D	0	-
300°C	0	-	1	B

MFR A - Raytheon

MFR B - Teledyne

NOTES:

- (A) $V_{CE} \geq .45V$
- (B) $I_{CBO} \geq 1.0 \mu A$
- (C) OPEN EMITTER
- (D) $h_{FE} \leq 22.5$



TABLE IX STEP STRESS PARAMETRIC FAILURE SUMMARY

JAN TX2N2484

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
100% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
125% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
150% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	0	-
100 hr.	0	-	1	A
100 hr.	0	-	0	-
250 hr.	0	-	0	-
175% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-

GROUP II 160 HR. TEMP. STEPS

TEST STEP (T _A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75°C	1	B	0	-
100°C	0	-	0	-
125°C	0	-	0	-
150°C	0	-	0	-
175°C	0	-	0	-
200°C	0	-	0	-
225°C	0	-	0	-
250°C	9	C	2	D
275°C	JOB STOPPED		-	
300°C	JOB STOPPED		-	

NOTES:

- (A) S/N #2164 FAILS $V_{CE(SAT)}$ MAXIMUM LIMIT
(B) S/N #2120 FAILS $V_{CE(SAT)}$ MAXIMUM LIMIT
(C) S/N #2122, 2124, 2125, 2126, 2128, 2131, 2133, 2134 - FAIL I_{CBO} MAXIMUM LIMIT
(D) S/N #2187, 2189 FAILS h_{FE} MINIMUM LIMIT
(E) S/N #2200 FAILS $V_{CE(SAT)}$ MAXIMUM LIMIT
(F) S/N #2197, 2207 FAILS $V_{CE(SAT)}$ MAXIMUM LIMIT
(G) S/N #2196, 2198, 2199, 2204, 2206 FAILS h_{FE} MINIMUM LIMIT
(H) S/N #2145 FAILS h_{FE} MAXIMUM LIMIT
(I) S/N #2145 FAILS I_{CBO} MAXIMUM LIMIT

GROUP III 16 HR. TEMP. STEPS

TEST STEP (T _A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150°C	1	E	0	-
175°C	0	-	0	-
200°C	0	-	0	-
225°C	0	-	0	-
250°C	0	-	0	-
275°C	2/5	F/G	1	H
300°C	0	-	1	I

MFR A - Raytheon

MFR B - Teledyne



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APPENDIX
FAILURE ANALYSIS



MSFC STEP-STRESS TEST
FAILURE ANALYSIS- TRANSISTORS

JANTX2N2484

Date 22 May 1978

J/N 2CN242-03B

P/N 2N2484

MFR: Raytheon Semiconductor

FAILURE VERIFICATION: Max = 10 nA Min = 45

S/N	V_{CE0} -volts-	V_{CB0} -volts-	I_{CB0} -uA- @ $V_{CB} = 45$ V.	V_{EB0} -volts-	h_{FE} @ $I_{CB} = 1.0$ uA; $V_{CE} = 5$ V.	V_{BE0} -volts- @ $I_{BE0} = 10$ mA	INITIAL REJ. @ test sequence #:	INITIAL REJ. FOR:
2120	open	8.0	--	open	--	--	03 (75° C)	CAT
				$V_{BE0} = 0.75$				
2122	73 Inv	144	1.2 uA	10.2	391 *	0.78	17 (250° C)	CAT
2128	0.48	100 Inv	2.2 uA	10.2	400 *	0.78	17 (250° C)	CAT

INTERNAL VISUAL INSPECTION:

All Raytheon samples have aluminum-gold intermetallic formation ("purple plague") on areas of the aluminum metallization.

S/N 2120: Emitter wire fused into a ball which rests on the emitter contact area.
(See figure A-1.)

S/N 2122 and 2128: No significant visual anomalies other than purple plague formation.

* h_{FE} trace present. Cannot meet stated test conditions.

** h_{FE} trace very leaky.

H = hysteresis

S = soft

D = drift

Inv = inversion

Uns = unstable

R = resistive



MSFC STEP-STRESS TEST
FAILURE ANALYSIS- TRANSISTORS

JANTX2N2484

Date 22 May 1978

J/N 2CN242-03B

P/N 2N2484

MFR: Teledyne Semiconductor

FAILURE VERIFICATION:

Max -

Min -

10 nA

45

S/N	V_{CE0} -volts-	V_{CB0} -volts-	I_{CB0} -uA- @ $V_{CB} =$ 45 V.	V_{EB0} -volts-	h_{FE} @ $I_C =$ 1.0 uA; $V_{CE} =$ 5 V.	V_{BE0} -volts- @ $I_{BE0} =$ 10 mA	INITIAL REJ. @ test sequence #:	INITIAL REJ. FOR:
2177	82H	184 OSC	1 uA	9.4	120	0.79	15 (225° C)	CAT
2178	100	174	1.0 nA	9.6	0.80	0.79	17 (250° C)	CAT
	$h_{FE} = 8.8$	@ $I_C = 50$ uA						
2189	83	150	1.0 nA	10.0	24		17 (250° C)	h_{FE}
	H	$h_{FE} = 45$	@ $I_C = 27$ uA;	55 @ $I_C = 50$ uA				

INTERNAL VISUAL INSPECTION:

All Teledyne samples have aluminum-gold intermetallics on areas of the aluminum metallization. The gold ball bonds are partly or wholly absent particularly on the base due to attack by the aluminum.

S/N 2177: The base lead has opened at the heel. (See figure A-2.)

S/N 2189: The die exhibits a crystalline deposit which was not removed by a light (20 second) treatment with glassivation etch.

Both S/N 2177 and 2189 had translucent, crystalline deposit on the outer (post) half of the internal wires. The deposit was completely removed by a 10 second rinse in flowing water.

* h_{FE} trace present. Cannot meet stated test conditions.

** h_{FE} trace very leaky.

H = hysteresis

S = soft

D = drift

Inv = inversion

Uns = unstable

R = resistive

CONCLUSIONS:

The Raytheon samples all suffer from excess leakage which can reasonably be ascribed to the movement of impurities resulting from excess die temperature. High die temperature is evidenced by the purple plague on all samples including S/N 2120 which was exposed to a maximum ambient of 75°C. In this case the melted emitter lead explains the source of the excess die temperature - namely, thermal run away. The appearance of the damage suggests that the wire was destroyed by a current which continued for a long time (minutes) and finally reached a flow greater than two amperes.

The h_{FE} fall-off exhibited by these samples is similar to that of the Raytheon transistors of Report No. JANTX2N2605. Refer to the first two paragraphs of the "Conclusions" section of that report.

Teledyne Semiconductor: The attack on the gold ball bonds is severe on all samples, and on S/N 2177 the base wire has opened as a result. The gold has flowed away from the wires into the aluminum to an unusual extent. (See Figure A-4.)

S/N 2177 was electrically unacceptable at the time of this analysis. S/N 2178 and 2189 have experienced a loss of h_{FE} . The explanation for this is the same as for the Raytheon samples above.

NOTE

Only one group of parts was subjected to failure analysis because it appeared that all the parts failed from the same failure mode, namely excessive heat stress.



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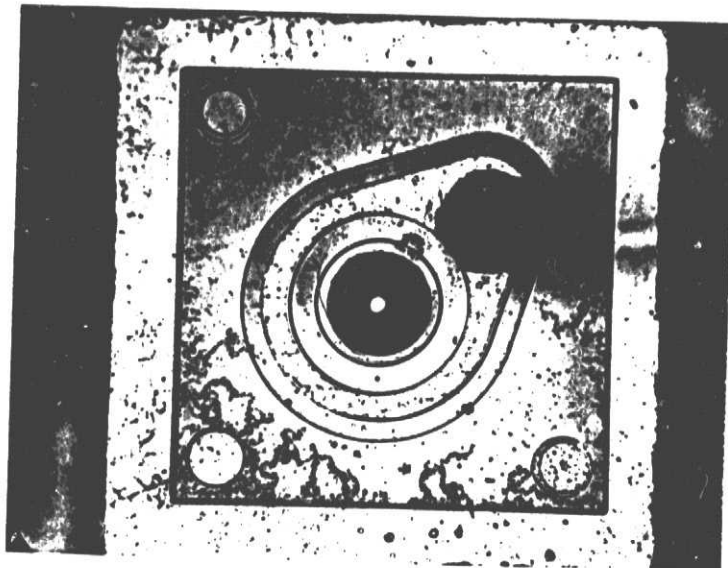


FIGURE A-1
S/N 2130 (Raytheon) at 152X. Note the gold emitter wire is open and has fused into a large ball on the emitter contact area.

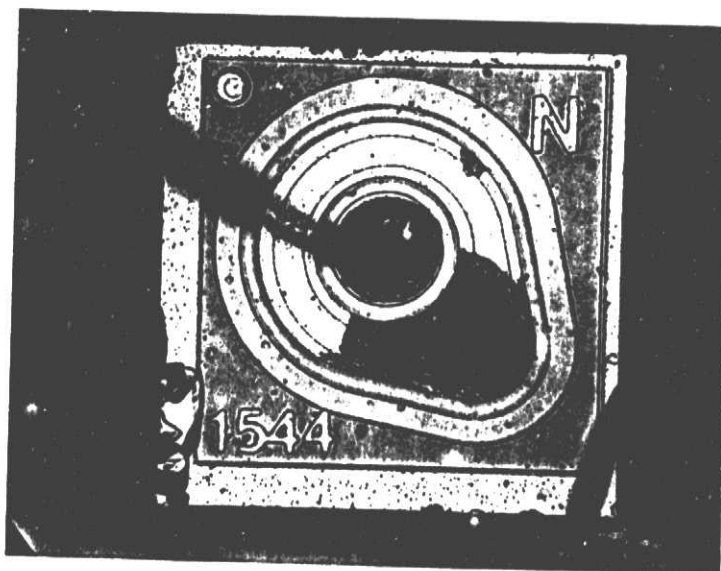
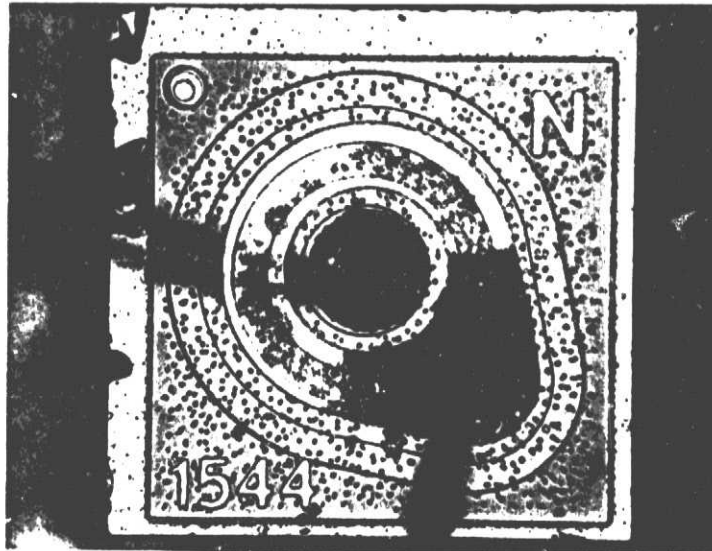


FIGURE A-2
S/N 2177 (Teledyne) at 152X. Die showing inter-metallic formation and open base wire.



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FIGURE A-3

S/N 2178 (Teledyne) at 176X. Contaminated Die.

Note: The cooler portions (outer half) of the wires also had a deposit which was removed by water.

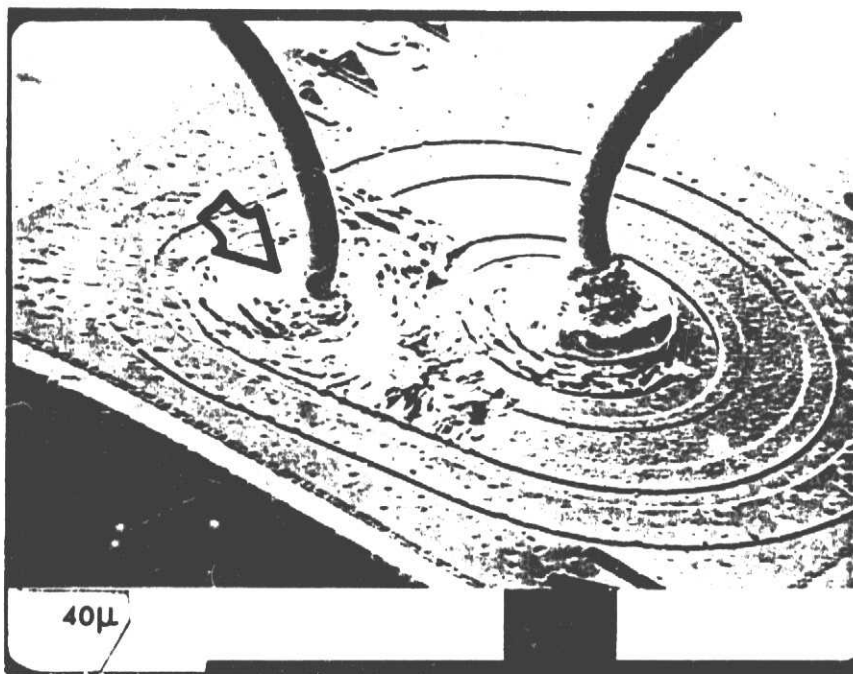


FIGURE A-4

S/N 2178 at 500X, 75°. Arrow indicates partial solution and disappearance of base leads.